QWIP-Based Thermal Infrared Sensor for the Landsat Data Continuity Mission

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Overview

- Background
- Project Overview
- Subassembly Description
- Focal Plane Design/Assembly
- Status
- Summary

Background

The NASA Landsat program has been in service since 1978 providing thermal imagery of the earth

The data has been used for a wide range of applications including:

- **Agricultural monitoring**
- **Cloud detection and analysis**
- **Mapping heat fluxes from cities**
- **Monitoring air quality**
- **Monitoring volcanic activity**
- **Monitoring the rain forests**
- **Biomass burning**
- **Industrial thermal pollution in the atmosphere, rivers and lakes**
- **Monitoring/tracking material transport in lakes and coastal regions**
- **Identifying insect breeding areas**

Landsat 7 was launched in 1999 with a 5 year mission life requirement

The Landsat Data Continuity Mission (LDCM) is scheduled to be launched in December 2012 to continue the Landsat Program legacy-joint NASA-USGS mission

The Thermal Infrared Sensor (TIRS) is a late addition 10.5-12.5 µm IR imaging instrument

Background

Detector Selection Rationale

Starting in 2004, studies were conducted at Goddard to recommend a detector technology for a thermal IR instrument on the upcoming Landsat Data Continuity Mission.

At that time only HgCdTe and microbolometers were considered. The selection criteria was based on:

- Performance requirements
- Availability
- Delivery schedule
- Cost

During this review it was determined that microbolometers were a more promising detector technology choice over HgCdTe based on cost and delivery schedule, even though technically the HgCdTe was more than adequate. QWIP technology was not considered because insufficient data existed on their longwave, broadband performance (8-12 μm).

The microbolometer-based instrument was pursued for ~3 years and then encountered technical, funding and programmatic issues (while the LDCM kept marching on with the main OLI instrument).

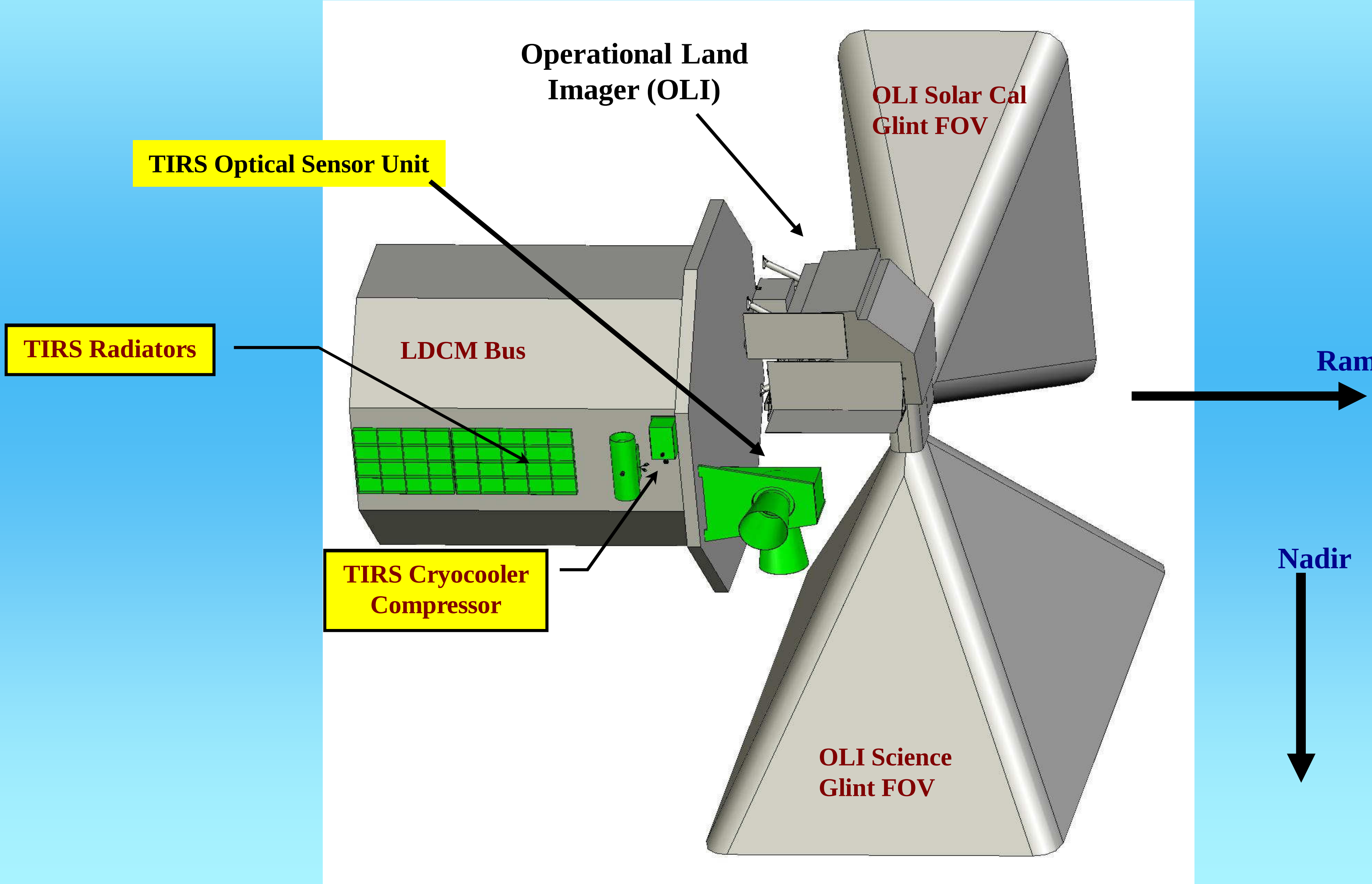
The entire TIRS concept was revisited in 2008 because:

- Performance limitations of microbolometers (time constant, TDI for NEΔT spec, low f/#)
- Severely reduced delivery schedule to start over
- Even more uncertainty to pursue MCT with reduced schedule and severe cost constraints
- Emergence of broad band far IR QWIP technology

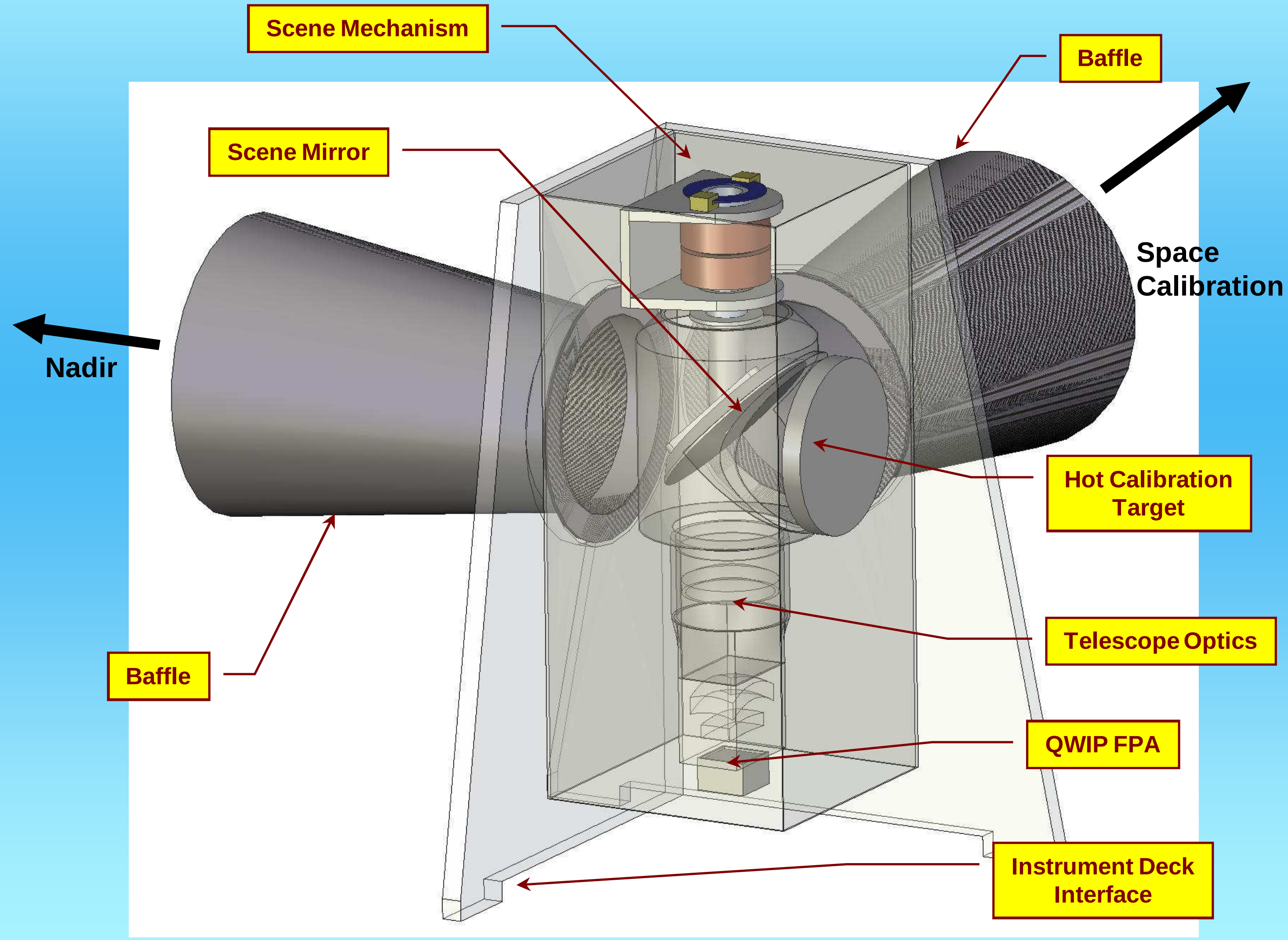
Project Overview

1. Design/fabricate a 640 x 512, 10.5-12.5 μm GaAs QWIP with an Indigo 9803 ROIC
2. Design/fabricate a custom silicon carrier board
3. Assemble 3 "Grade A" QWIP hybrids into a Flight Focal Plane Assembly (FPA)
4. Install narrow bandpass filters
5. Perform radiation (gamma, protons, heavy ions) and environmental tests
6. Incorporate Teledyne "SIDECAR" ASIC into control electronics
7. Fully characterize the arrays and the Flight FPA
8. Delivery of a Flight and Flight Spare required by July 2010 (<2 years start to finish)

Landsat Data Continuity Mission Spacecraft



TIRS Instrument Concept



TIRS Focal Plane Requirements

-Spacecraft altitude:	705 km
-Across track speed:	7 km/sec
-Two spectral bands centered at :	10.8µm, 12.0µm
-NEΔI (320K)	0.059/0.049 W/m^{2}sr µm
-Optics (T~160K):	f/1.64
-Pixel size:	25µm x 25µm
-Ground resolution:	100m/pixel
-Operating temperature:	43K
-Focal plane thermal stability:	<0.01K

Science data requirement:

Two rows each containing 1920 pixels of 10.8 µm and 12.0 µm band data are acquired in each image frame. The data from both rows in each band may be combined such that one contiguous row of science data containing only 1 inoperable pixel (in the combined rows) is obtained for each band such that a single effective row of image data is formed.

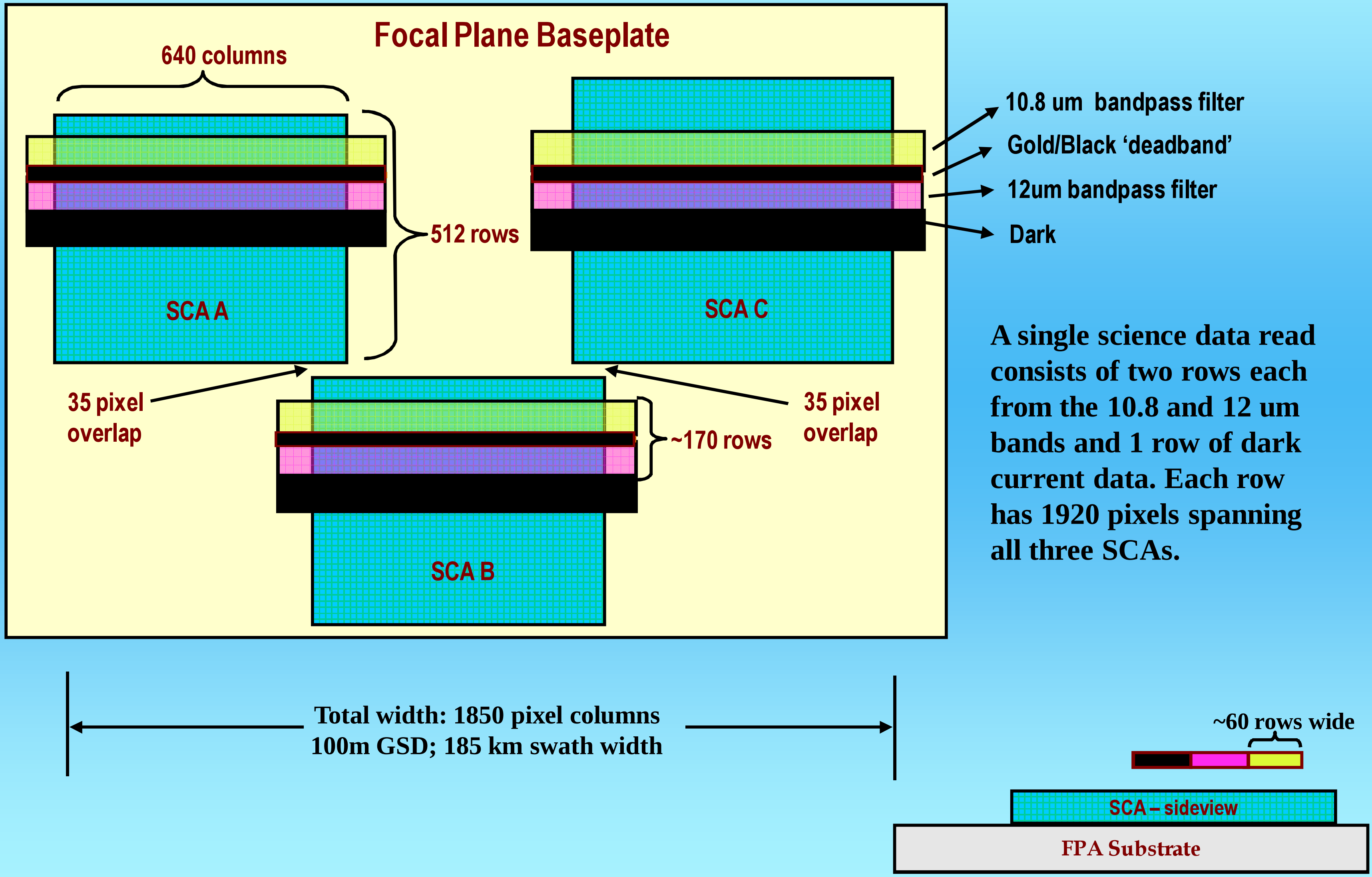
Operability defined as:

-Read noise	<1,000e-
-Dark current (I_D)	<7E8 e-/sec (17µA/cm^2)
-Conversion efficiency (CE)	>2.5% from 10.5-12.3 µm
-CE at 7 µm	<1%
-CE from 2-7 µm	<0.1%
-CE at 14 µm	<1%
-CE from 14-20 µm	<0.1%
-Full well capacity	>5Me- (11Me- max)
-CE stability at nom. stable operating conditions	<0.1% of mean over 34 min
-I_D variation at nom. stable operating conditions	<0.2% of mean over 34 min

-When mounted to the invar baseplate, the photoactive area of the 3 detector arrays shall all be within ± 6.5 µm of each other.

-The FPA will survive 40 thermal cycles from ~300K-77K.

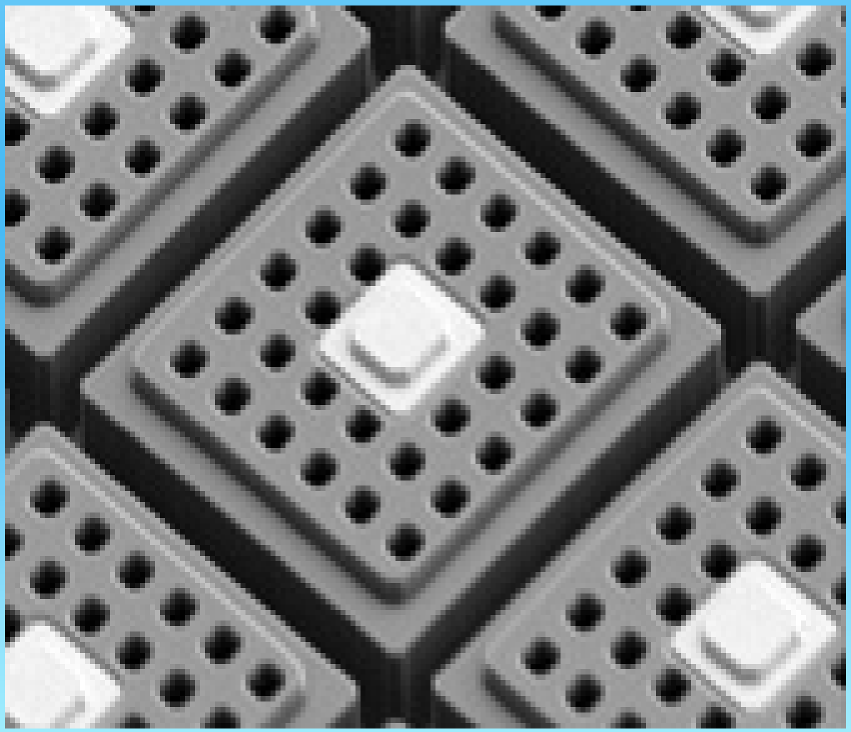
TIRS Focal Plane Overview



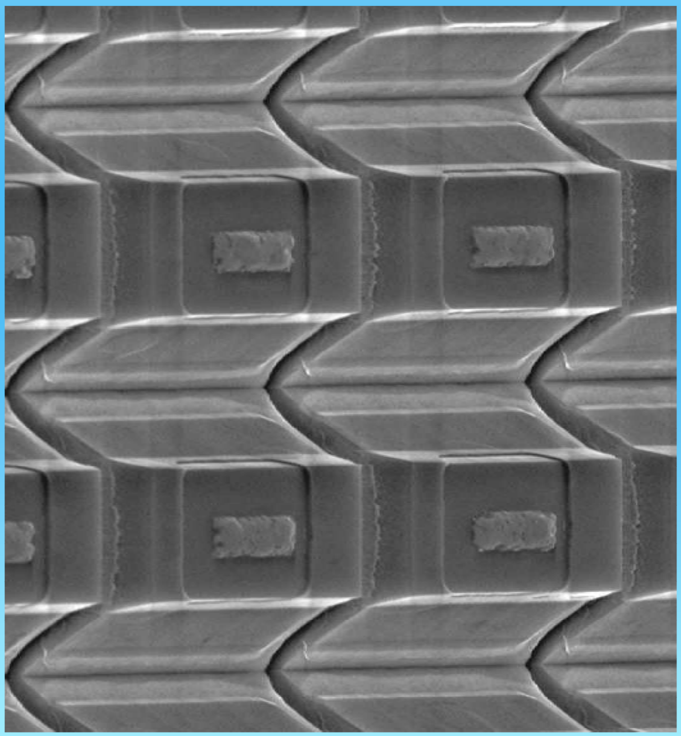
A single science data read consists of two rows each from the 10.8 and 12 um bands and 1 row of dark current data. Each row has 1920 pixels spanning all three SCAs.

Pixel Photos

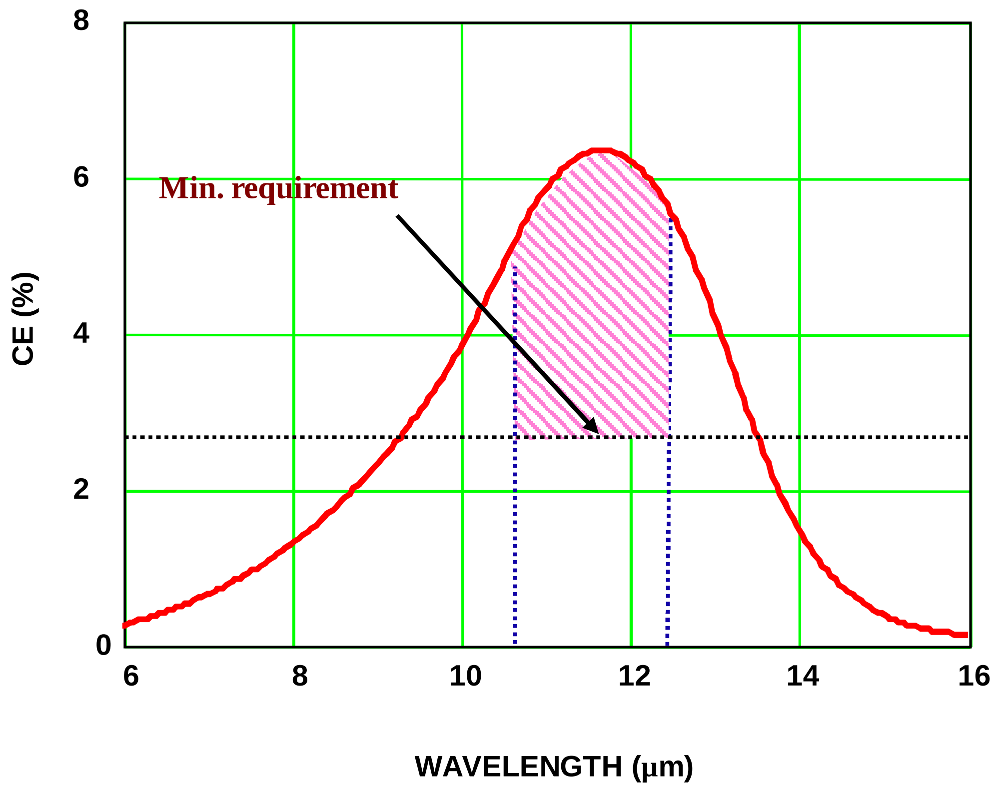
QmagiQ Pixel with Grating
Lower QE, Higher g



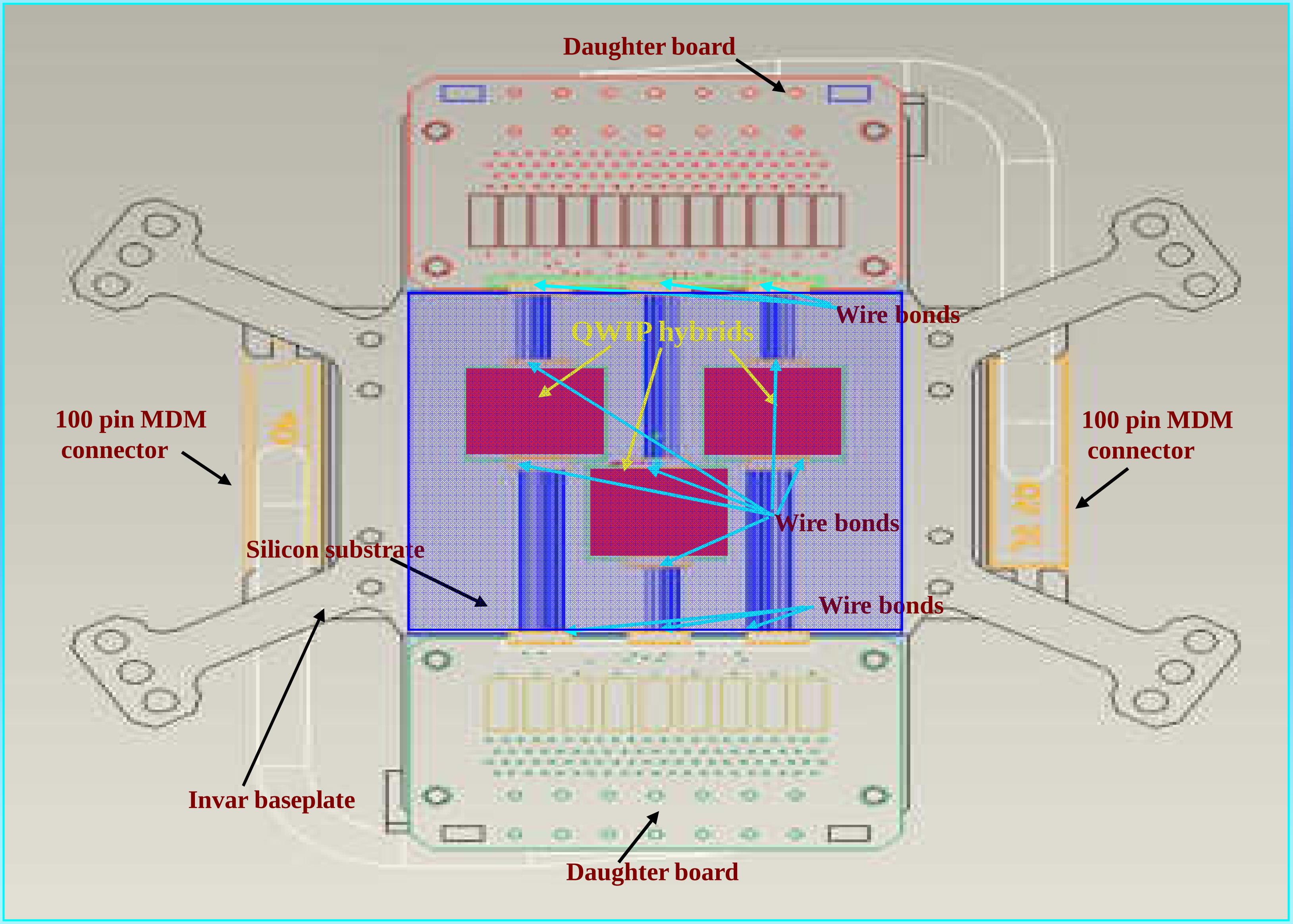
ARL/GSFC Corrugated QWIP structure
Higher QE, Lower g



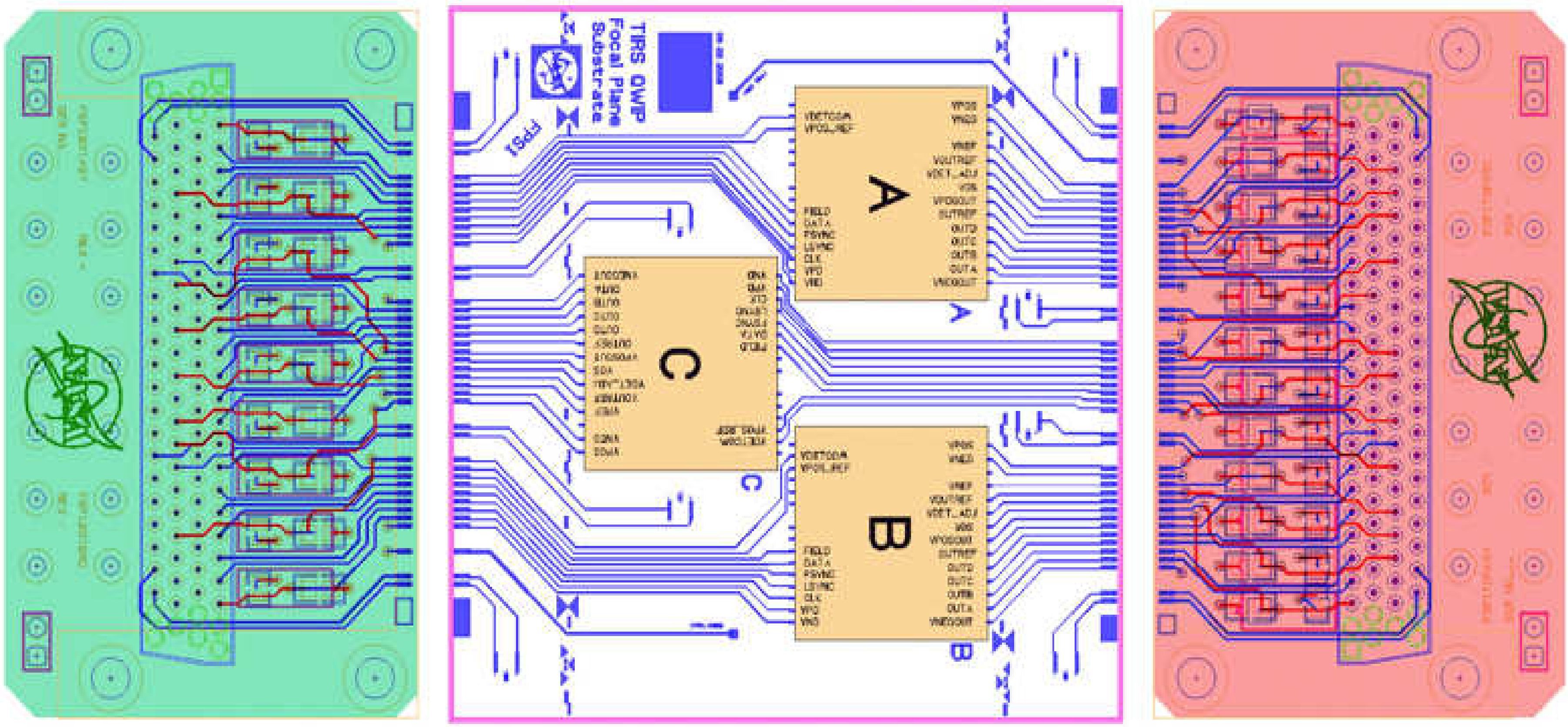
TIRS 10-13 µm QWIP
Spectral Response Requirement



Focal Plane Layout



TIRS QWIP Focal Plane Electrical Layout



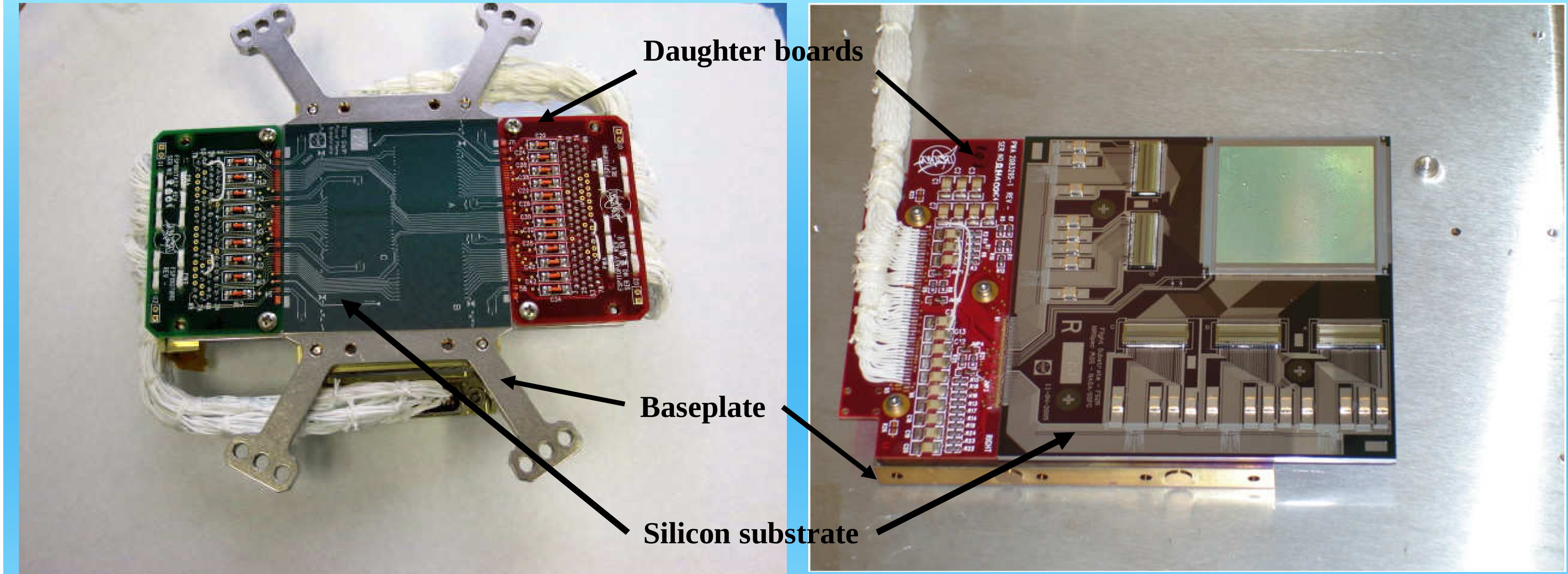
Daughter Board I

Silicon Substrate

Daughter Board II

Silicon Substrate Mounted on the Baseplate with Daughter Boards

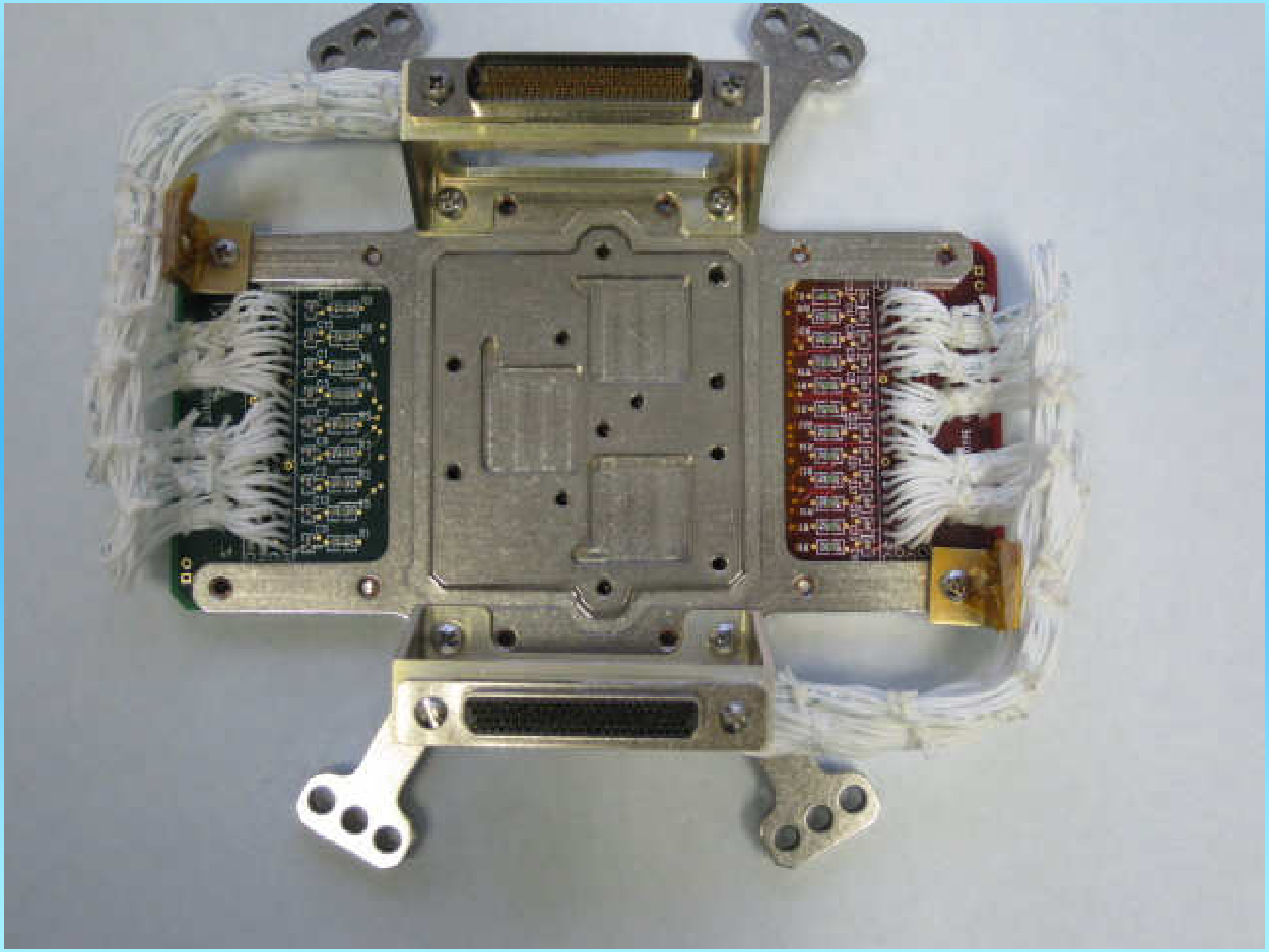
(Design Based on Proven Heritage)



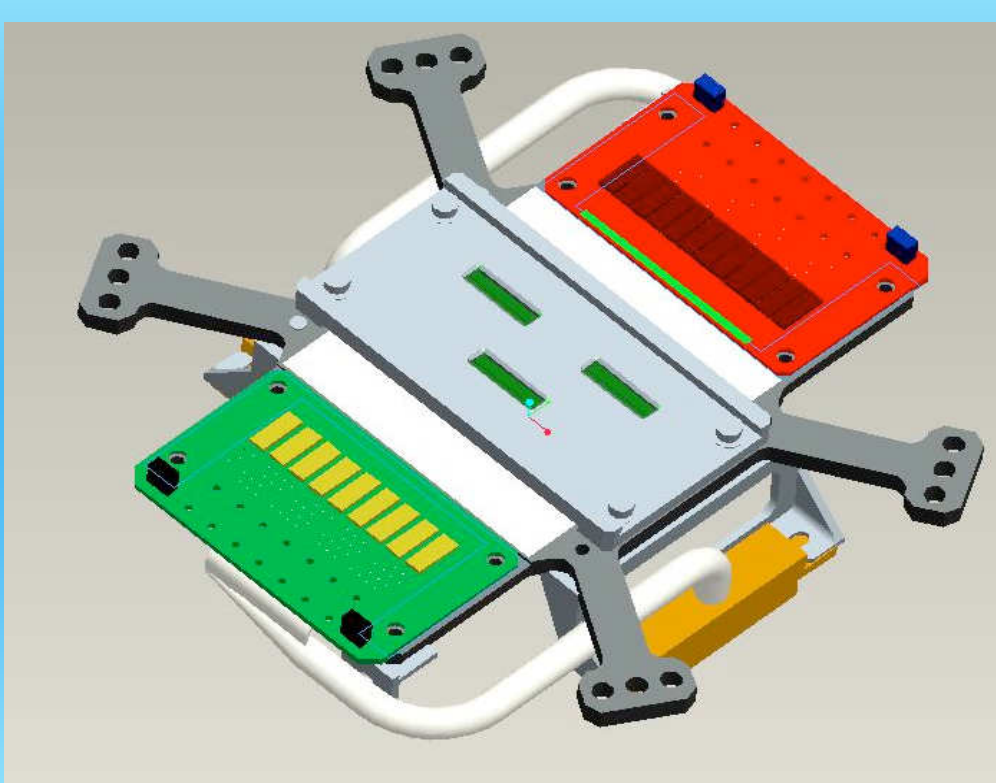
TIRS Focal Plane Assembly

Microshutter Array Assembly for the James Webb Space Telescope

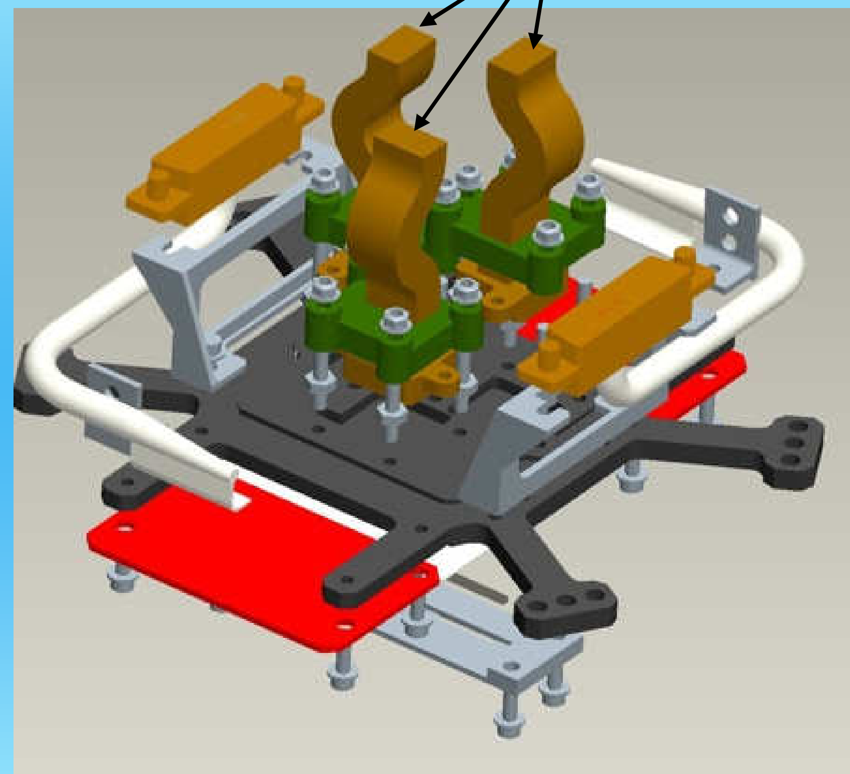
Silicon Substrate Mounted on the Baseplate with Daughter Boards



Focal Plane Assembly

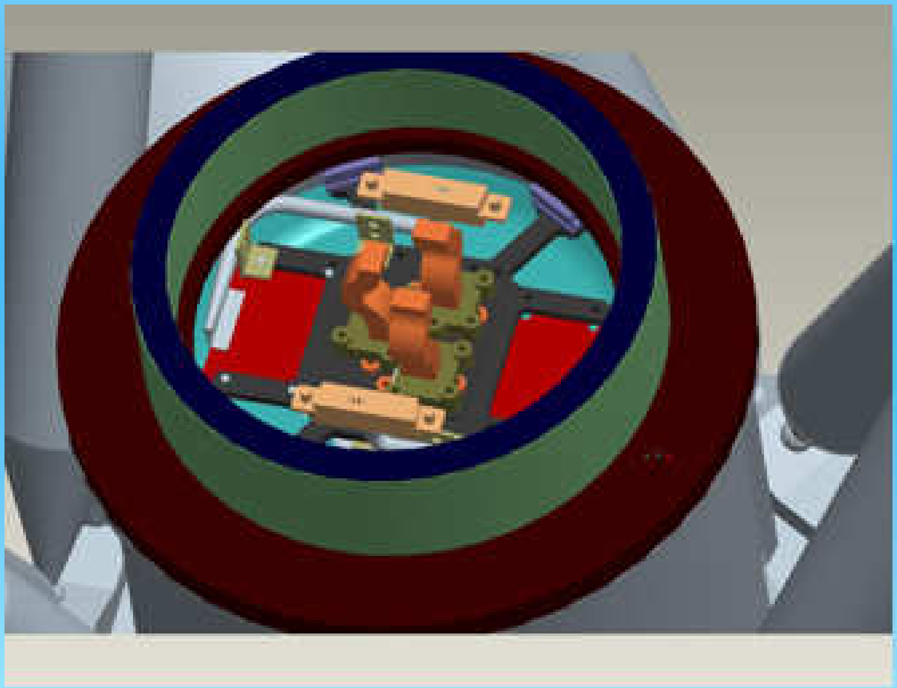


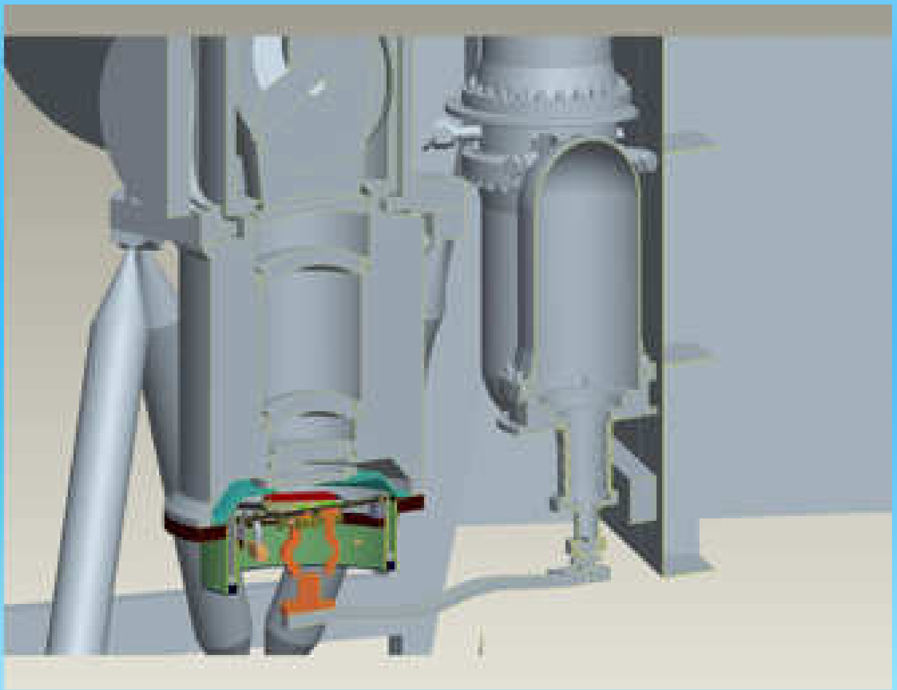
Fully assembled FPA
Front side



Fully assembled FPA
Back side

Focal Plane Assembly Integrated with TIRS





Required TIRS Focal Plane Assemblies

In addition to our internal test articles the following 4 units will be built:

1. **Pathfinder (April, 09)**
   - Required for process, assembly and test development
   - Environmental qualification (vibration, acoustics, shock, T-V)
   - 1-3 ROICs , Grade B/C hybrids (ROIC with QWIP array) or a mixture
2. **Engineering/Flight-like Model (June, 09)**
   - For system level testing
   - 3 Grade B or C hybrids
3. **Flight Unit (Jul, 10)**
   - Grade A hybrids
4. **Flight Spare (Jul, 10)**
   - 3 Grade A hybrids

Grade Description

Grade A--Meets all Flight specifications
Grade B--Fully functioning with a few bad rows/columns
Grade C--Partially functioning

Current Status

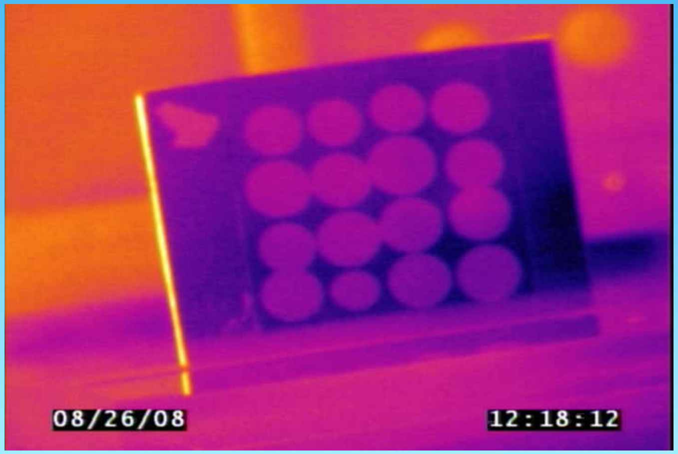
- We have performed Co^{60} gamma radiation on the Indigo ROIC to 30Krads with no degradation.

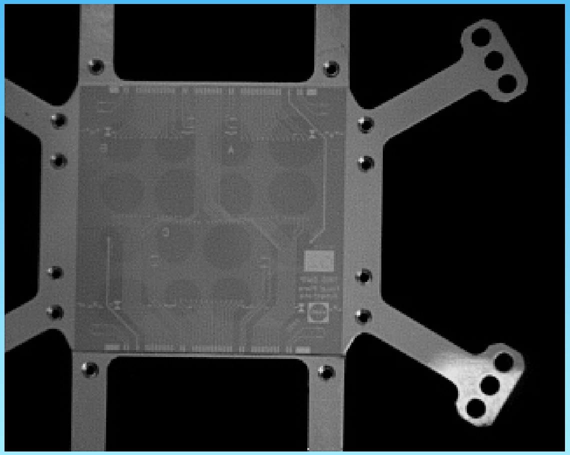
- We have performed proton radiation testing on QmagiQ 8.4µm QWIP hybrids with no degradation (some single event anomalies occurred).

- The first batch of QmagiQ QWIP arrays have been fabricated and are currently being tested.

- All mechanical and electrical elements (silicon substrate, daughter boards and flight hardware) are ready for assembly.

- Thermal tests have been performed on key component interfaces.





- Currently building the first “pathfinder” assembly.

Summary

- We have a unique opportunity to develop a QWIP-based earth observing instrument for one of the nations pre-eminent resources-the Landsat Program.
- The project is pursuing an extremely aggressive path to meet schedule.
- The collaborative and extremely interactive relationship between Goddard, the Army Research Lab, QmagiQ and our vendors is absolutely key to the success of this project.
- Much of the design and fabrication is based on Space Flight hardware developed for previous NASA missions (most notably the James Webb Space Telescope).
- All hardware has been designed and fabricated, current emphasis is on the QWIP development.

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